

## 33-131 Exam 1, Tuesday 2000 Sept. 26

Name \_\_\_\_\_

- Read all problems carefully before attempting to solve them.
- Your work must be legible, and the organization must be clear.
- Correct answers without adequate explanation will be counted wrong.
- Incorrect explanations mixed in with correct explanations will be counted wrong.
- Make explanations complete but brief. Do not write a lot of prose.
- Include diagrams!
- Show what goes into a calculation, not just the final number:  $\frac{(8 \times 10^{-3})(5 \times 10^6)}{(2 \times 10^{-5})(4 \times 10^4)} = 5 \times 10^4$
- Give physical units with your results.

If you cannot do some portion of a problem, invent a symbol for the quantity you can't calculate (explain that you're doing this), and do the rest of the problem.

Problem Score

1 (25 pts): \_\_\_\_\_

2 (30 pts): \_\_\_\_\_

3 (25 pts): \_\_\_\_\_

4 (20 pts): \_\_\_\_\_

5 (3 pts): \_\_\_\_\_

Total (100 pts): \_\_\_\_\_

**Problem 1 (25 pts):** One mole of nickel ( $6 \times 10^{23}$  atoms) has a mass of 59 grams, and its density is 8.9 grams per cubic centimeter. You have a bar of nickel 2.5 m long, with a square cross section, 2 mm on a side. You hang the rod vertically and attach a 40 kg mass to the bottom, and you observe that the bar becomes 1.2 mm longer.

Next you remove the 40 kg mass, place the rod horizontally, and strike one end with a hammer.

How much time  $T$  will elapse before a microphone at the other end of the bar will detect a disturbance? Be sure to show clearly the steps in your analysis.

**Problem 2 (30 pts):** A hockey puck with mass 0.4 kg is sliding along the ice with velocity  $(20, 0, 0)$  m/s. As the puck slides past location  $(5, 3, 0)$  m on the rink, a player strikes the puck with a sudden force in the  $+y$  direction, and the hockey stick breaks. A short time later, the puck's position on the rink is  $(9, 12, 0)$  m. When we pile weights on the side of a hockey stick we find that the stick breaks under a force of about 1000 N.

(a, 27 pts) For approximately how much time  $t_{\text{contact}}$  was the hockey stick in contact with the puck? Be sure to show clearly the steps in your analysis.

(b, 3 pts) What approximations and/or simplifying assumptions did you make in your analysis?

**Problem 3 (25 pts):** In a container of gas in outer space, a neutral oxygen atom with mass  $m_1$  and momentum  $(p_{x1}, p_{y1}, p_{z1})$  approaches a neutral chlorine atom of mass  $m_2$  and momentum  $(p_{x2}, p_{y2}, p_{z2})$ . The oxygen atom exerts an attractive electric force on the chlorine atom of magnitude  $F = k/r^7$ , where  $r$  is the distance from the center of the oxygen atom to the center of the chlorine atom, and  $k$  is a known constant. (This force is called a Van der Waals' force. For this problem you do not need to know *why* it occurs.)

Write a computer program in VPython to predict and display the future motion of the two atoms (the initial conditions are such that they pass each other and do not bind to each other). It is not necessary to get the details of program syntax correct, as long as you explain your logic and calculations clearly, and the steps follow a logical sequence. You do need to include all statements necessary to carry out the computation. We provide part of the initial setup.

**from visual import \***

**oxygen = sphere(pos=vector(x1,y1,z1), radius=r1)      # x1,y1,z1, and r1 are known quantities**

**chlorine = sphere(pos=vector(x2,y2,z2), radius=r2)      # x2,y2,z2, and r2 are known quantities**

**Problem 4 (20 pts):** Two students are running to classes in opposite directions. They run into each other head-on and stop abruptly. Using physics principles, estimate the force that one student exerts on the other during the collision. You will need to estimate some quantities; give reasons for your choices. (See the back page for English/metric conversion factors. )

**Problem 5 (3 pt bonus question)**

If you get a total score greater than 100, we round down to 100. Since this problem is only worth 3 bonus points, don't attempt it unless you have finished all the other problems and checked your work.

In the approximation that the Earth is a sphere of uniform density, it can be shown that the gravitational force it exerts on a mass  $m$  inside the Earth at a distance  $r$  from the center is  $mg(r/R)$ , where  $R$  is the radius of the Earth. (Note that at the surface, the force is indeed  $mg$ ). Suppose that there were a hole drilled along a diameter straight through the Earth, and the air were pumped out of the hole. If an object is released from one end of the hole, how long will it take to reach the other side of the Earth? Include a numerical result.

## Fundamental Principles and Force Laws

Newton's laws of motion

The principle of relativity

The superposition principle

The gravitational force law

The spring force law

## Specific results and data

$$Y = \frac{F/A}{\Delta L/L} = \frac{k_s}{d} \quad \omega = \sqrt{\frac{k_s}{m}} \quad v = d \sqrt{\frac{k_s}{m}} \quad \left| \frac{d\vec{x}}{dt} \right| = \omega |\vec{x}|$$

$$G = 6.7 \times 10^{-11} \text{ N}\cdot\text{m}^2/\text{kg}^2$$

$$g = 9.8 \text{ N/kg}$$

$$M_{\text{Earth}} = 6 \times 10^{24} \text{ kg}$$

$$M_{\text{Moon}} = 7 \times 10^{22} \text{ kg}$$

$$\text{Radius of the Earth} = 6.4 \times 10^6 \text{ m}$$

$$\text{Radius of the Moon} = 1.75 \times 10^6 \text{ m}$$

$$\text{Distance from Sun to Earth} = 1.5 \times 10^{11} \text{ m}$$

$$\text{Distance from Earth to Moon} = 4 \times 10^8 \text{ m}$$

$$\text{Avogadro's number} = 6 \times 10^{23}$$

$$m_{\text{proton}} \approx m_{\text{neutron}} \approx m_{\text{hydrogen atom}} = 1.7 \times 10^{-27} \text{ kg} \quad m_{\text{electron}} = 9 \times 10^{-31} \text{ kg}$$

## Conversion factors

$$1 \text{ pound} = 0.45 \text{ kilogram}$$

$$1 \text{ kilogram} = 2.2 \text{ pounds}$$

$$1 \text{ mile} = 1600 \text{ meters}$$

$$1 \text{ inch} = 2.54 \text{ centimeters}$$

$$1 \text{ hour} = (60)(60) \text{ s} = 3600 \text{ s}$$